
Minimum Yellow Change Interval for Intersections with Red-Light Camera Enforcement in California

Hamid Bahadori, PE, TE, PTOE
Principal Transportation Engineer
Automobile Club of Southern California (AAA)
Chairman, California Traffic Control Devices Committee (CTCDC)

A. BACKGROUND

Municipalities in California have been traditionally using the Caltrans *Traffic Manual* (recently replaced with the 2003 edition of the MUTCD, *Manual on Uniform Traffic Control Devices*, as amended with the *California Supplement*) for design, operation and maintenance of traffic control devices throughout the state. As part of this practice, signal timing practitioners use Table 4D-102 of the *California Supplement*, replacing Table 9-1 of the old *Traffic Manual*; only in numbering and not in content. Table 4D-102 recommends minimum timing values for the yellow change intervals based on the "Approach Speed" of the vehicles. However, the 2003 MUTCD and the *California Supplement* do not offer a clear definition of "Approach Speed", and they also remain silent on whether these minimum timing values should also equally apply to protected left-turn phases as well. Due to these ambiguities, different jurisdictions in California had been using different interpretations on both questions, resulting in different minimum yellow change intervals for identical conditions, even within the same jurisdiction.

Although the need for clarification of this issues had been discussed for a long time, the recent increase in the installation of the automated red-light photo enforcement devices, and the change in the state law (Assembly Bill 1022 sponsored by the Automobile Club of Southern California), made this a more urgent matter to be addressed by the California Traffic Control Devices Committee (CTCDC) in order to develop a uniform policy for use in California.

AB 1022 introduced the following section to the California Vehicle Code (CVC):

21455.7. (a) At an intersection at which there is an automated enforcement system in operation, the minimum yellow light change interval shall be established in accordance with the Traffic Manual of the Department of Transportation.

However, the aforementioned ambiguities and different interpretations of the old *Traffic Manual* (now Table 4D-102 of *California Supplement*) did not only result in legal challenges to the tickets issued by the automated devices, with thousands being successful, it also created confusion among municipalities using theses devices as to what "legally defensible" yellow change interval timing values were.

Furthermore, field studies demonstrated that increasing the yellow timings at several intersections with red-light cameras, in the City of San Diego, by only 1 to 1 ½ seconds, would decrease the number of tickets issued by the cameras from about 3,000 per month to less than 500.

In order to resolve this issue the following two questions needed to be answered:

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1. Should the "Approach Speed" be more clearly defined, and if so how; i.e., posted speed limit, 85th percentile speed, etc?
 2. Should the same "Approach Speed" be used to establish the minimum yellow change interval for all movements including the protected left turns? If not, how should the recommended minimum values be adjusted for the protected left turn phases?

The California Traffic Control Devices Committee (CTCDC), in reply to a request by the Automobile Club of Southern California (AAA), formed a subcommittee to review this issue, and report back to the Committee. This paper presents the CTCDC discussions and its final recommendations on the subject.

B. DISCUSSION

"At the termination of a green phase, motorists approaching a signalized intersection are advised by a yellow signal indication that the red interval is about to commence. The speed and location of some approaching vehicles will be such that they can stop safely at the stop line; others will have to continue at their speed or even accelerate into or through the intersection. The minimum length of the clearance interval (which may include an all-red interval after the yellow indication) should accommodate both situations and eliminate the possibility of a dilemma zone in which a driver can neither stop safely nor legally proceed into or through the intersection." (*Transportation and Traffic Engineering Handbook*; Second Edition; Institute of Transportation Engineers; p. 756) As logical and easy to understand the above statement may appear, the calculation of yellow change interval timing has been the subject of many engineering and research studies resulting in various methodologies and formulas.

As Philip Tarnoff, a nationally recognized authority on signal timing acknowledges: "Although the calculation and implementation of traffic signal clearance intervals is relatively straightforward, a surprising number of issues are associated with their use." (*Traffic Signal Clearance Intervals*; Tarnoff, Philip; ITE Journal; April 2004). He further explains that part of the challenge might be due to the fact that "there are at least three techniques in use for calculation of yellow time. (There are four if one counts the third term of the kinematic equation as an alternative.)" In his conclusion, Tarnoff acknowledges that "the lack of national uniformity is due to historical usage and the need to accommodate local conditions."

Although a technical discussion of the merits of each of these methodologies is a worthy effort, the CTCDC decided to narrow its focus on the methodology historically used in California as the CVC Section 21455.7 had clearly assigned the Caltrans *Traffic Manual* as the authority for calculation of the yellow change interval timing. Therefore, for the all the CTCDC discussions, Table 4D-102 of the *California Supplement*, and the methodology and formula used to calculate its recommended values were considered as the only valid methodology for the State of California.

This assumption focused the extent of the review and recommendations to only establishing a clear, concise and uniform definition of the "Approach Speed", and the need for any adjustments to the Table 4D-102 minimum yellow timing values for the protected left-turn phases.

Lack of a clear definition of "Approach Speed" in the 2003 MUTCD and *California Supplement* might have been intentional by the original authors to offer flexibility to practitioners to

accommodate specific intersection needs. However, regardless of the authors' intent, the outcome of this flexibility was an inconsistency in calculation of the yellow change interval clearance time among different agencies, and even different assumptions for the "Approach Speed" by the same agency at different intersections within their jurisdiction. This, obviously, was not a desirable situation and also had legal implications for the intersections using automated red-light photo enforcement devices.

In developing a concise and uniform definition for the "Approach Speed", traffic safety must be the paramount concern with secondary considerations given to operational issues such as cycle lengths and avoidance of undue lost time for the available green phases. Furthermore, practical implications of this definition such as availability of data, speed measurements and uniformity of application needed to be considered as well.

The following alternatives were developed and discussed by the CTCDC for potential definitions of the "Approach Speed" in Table 4D-102 of *California Supplement*.

1. Use posted speed limit as "Approach Speed"

The most obvious and the simplest to use alternative will be to simply define the "Approach Speed" as the posted speed limit, or the prima facie speed for un-posted arterials. An advantage of using the posted speed is its availability for the field practitioners. If the arterial has a posted speed limit, a field technician can simply use the posted speed limit in application of Table 4D-102 to determine the yellow change interval. For arterials that do not have a posted speed limit, the CVC assigns the prima facie speed, which is commonly known and can be applied in using the Table 4D-102.

Another advantage of using the posted speed limit as "Approach Speed" is that this is the "legally established" speed for the arterial, and may be more defensible in courts for cases involving the automated red-light violation tickets.

However, this approach may not offer the safest condition for approaching vehicles, and will generally result in a shorter yellow change interval. For example, the City of Costa Mesa, California found 80% of posted speed limits having higher 85th percentile speeds (132 locations out of 165 total speed surveyed locations). On a cumulative citywide scale, the City found that the posted speed averaged 2.78 MPH less than the 85th percentile.

Posted speed limits, in California, are usually a few miles below the measured 85th percentile speeds, as they are rounded downward to the nearest 5-mile increment of the 85th percentile speed. Additionally, in many locations due to local concerns or to accommodate community pressures, the posted speed limits are lowered using the provision of "conditions not readily apparent to the drivers" such as proximity to schools, presence of pedestrians or equestrian, etc. Therefore, exclusively applying the posted speed limit for calculation of the yellow clearance time may not achieve the goal of eliminating the dilemma and may cause trap conditions by forcing motorists in an unsafe manner into intersections, or sudden and unexpected stops resulting in a higher number of rear-end collisions.

However, it may be argued that the variance between the "posted" speed and the 85th percentile speed is, in the great majority of cases, within a range of 0 to 4 MPH, and given that intersection approach speeds are typically less than the mid-block 85th percentile speeds, a compromise to safety through applying the "posted" speed limit may not be significant due to such relatively

small variations. But in cases where the posted speed limit could be lower than the 85th percentile by as much as 9 MPH, using the posted speed limit to determine the minimum yellow change interval will obviously have an adverse effect on traffic safety. These circumstances would require special engineering judgment beyond the simple determination of yellow timing based solely on the posted speed limit.

It can also be further argued that the posted speed limit is the speed adopted for the roadway segment as designated by the responsible legislative body, and is established as the law to be obeyed. Assuming proper engineering studies are the basis, the posted speed limit supersedes all supporting data including the 85th percentile speeds. The 85th percentile is only one factor in establishing the legal speed limit. Even though the posted limit is generally based on 15% of drivers exceeding it, it is established as the legal limit. Therefore, using any speed higher than the “posted speed” begs the question if engineers should be expected to use a higher speed than what has been determined to be “legal”, to determine the yellow clearance.

Nonetheless, using speeds higher than posted speed limits for operational purposes such as signal coordination projects is a rather common practice in many jurisdictions.

The dichotomy of these two opposing arguments is mostly due to the fact that the primary objective of using 85th percentile speed to reach at a “legally posted speed limit” is a regulatory function, versus using it to “calculate the minimum yellow change interval” which is to enhance traffic safety through providing adequate clearance timing. Therefore, the objectives of these two activities are inherently different.

Nonetheless, applying the posted speed to determine yellow clearance has been the standard practice among many agencies, and is more easily defensible in legal proceedings. The traffic engineering profession recognizes that this application is commonly supplemented, without any specific guidelines for these adjustments, to cover potential anomalies in approach speed.

Based on such applications of the posted speed limit, enforcement agencies acknowledge that motorists have had adequate time to react to the yellow change interval. Legal challenges are rarely encountered where a defendant disputes the adequacy of yellow time based on the appropriately set posted speed limit. In most recent red light running court hearings, where yellow interval settings are debated, the focus has been mostly on discrepancies in yellow timing “methodology” and not the deficiencies in yellow time itself. This discrepancy in yellow timing “methodology” is the impetus for establishing clearer approach speed standards.

Therefore if the historical application of posted speed to determine yellow clearance is typically not found deficient, and given the posted speed limit is the agency established legal speed, then it can be argued that the posted speed limit should be the standard criteria for “Approach Speed”.

2. Use the 85th percentile speed as “Approach Speed”

Another alternative to define “Approach Speed” is to use the actual 85th percentile speed as the “Approach Speed”. Although this approach may address many of the safety concerns, it has several constraints in its actual application.

First, the 85th percentile speed is a “raw” number and seldom is at exact 5-MPH increment that is needed in the application of Table 4D-102. Therefore, some kind of adjustment to the precise 85th percentile speed must be made to make it useful in determining the minimum yellow change

interval value in Table 4D-102. This adjustment should be in “rounding” of the 85th percentile speed to the nearest (up or down) 5-mile increment. To improve traffic safety, it will be desirable to round up the 85th percentile speed to the nearest 5-mile increment, as it will yield a higher value for the minimum yellow change interval. However, this added time, may have little significance in improving traffic safety while lowering the efficiency of the intersection.

Second, speed surveys to determine the 85th percentile speed are always taken away from the proximity of signalized intersections to benefit from the relatively free flow conditions. An argument may be made that these speeds, as a result, are not truly representative of the speed of vehicles approaching the traffic signal. The correct definition of “Approach Speed” is the speed of vehicles approaching the signalized intersection, which is invariably different than the mid-block travel speed obtained from standard speed studies. Therefore, a true representation of the approach speed based on the 85th percentile would require that separate speed surveys be conducted at the approaches of each intersection, which would then comply with the correct intent and more critically, be “legally defensible”. The effort to compile this extent of speed data for each intersection approach would be well beyond the capability of most agencies. For example, City of Los Angeles having more than 4,000 traffic signals, will need to conduct over 16,000 speed surveys to determine the new “intersection 85th percentile speeds”, and they will need to be regularly monitored and updated as well.

It may be also argued that the 85th percentile speeds typically change with each radar study; therefore, creating a moving target. Such ongoing changes in clearance time may cause complications with extended court proceedings and with signal timing and maintenance personnel. As an example, the City of Costa Mesa, California compared radar speed surveys from 1999 and 2004 and found an overall average vehicle speed change of 2.6 MPH, with 15% of studied locations changing by 5 MPH or greater. This range of variation and associated implications in changing the yellow clearance would have negative consequences relative to operations, maintenance and legal liability.

Consequently, applying the 85th percentile speed may result in significantly more changes to yellow clearance time on an ongoing basis with associated increased potential in litigation exposure; whereas, use of the posted speed limit may minimize timing variations should continued application of the posted speed be determined safe as is generally acknowledged.

It may also be argued that the 85th percentile speed still does not account for the 15% of motorists exceeding this theoretical limit anyway. Safety factors for motorists within this 15% margin would remain unrecognized by adjustments to the clearance time, similar to those traveling over the “posted speed limit”, if that speed is used as the “Approach Speed”; therefore, using the 85th percentile speed will not completely resolve the safety concerns associated with the use of “posted speed limit” anyway.

3. Use posted speed limit plus 5 miles as “Approach Speed”

This alternative has the benefit of using the readily available posted speed limits while addressing the safety concerns of using the posted speed limit directly for calculation of the yellow clearance timings. This may be a more conservative approach compared to alternatives 1 and 2, and will result in a higher value for the yellow phase. This alternative may improve traffic safety, but may adversely reduce the efficiency of the signalized intersections by allocating more time to the yellow clearance at the expense of shorter green phases. Engineers have recognized that yellow clearance time operationally serves as an extension of the effective green time for the motoring public; therefore, this impact may not be significant. However this approach is in opposition to

the premise that the agency adopted posted speed limit is the speed limit recognized by law. Furthermore, there is not any reasonable and legally defensible argument for the use of the arbitrary 5 MPH increase to the posted speed limit for calculation of the minimum yellow change intervals

4. Develop a hybrid alternative for different conditions

In order to maintain flexibility for the field practitioners while having a uniform standard throughout California, it may be desirable to develop a hybrid alternative to accommodate various filed conditions. This alternative incorporates a combination of the three aforementioned options and recommends specific guidelines for their respective uses.

As an example, one alternative could be to apply the higher of either the posted speed limit or the 85th percentile. Another alternative could be to apply the 5-MPH incremental increase to either of the higher values to provide a potential increase in safety. In either case, this could lead to inconsistencies in application, complications with signal engineers and maintenance personnel and potential legal issues. This alternative would not have improved the existing conditions.

5. Adjustments for protected left-turn phases

The 2003 MUTCD and *California Supplement* do not make any recommendations regarding the reduction of the minimum yellow clearance timings shown in Table 4D-102. However, it is a common practice among practitioners to use a reduced value for the protected left turn phases compared to the through movements for the same approach. This practice is mostly for allowing more time for the green time. It is also argued that the left turning vehicles have a lower “Approach Speed” compared to those who travel straight through the intersection. Although this argument may be true for many cases, it may not be the case for relatively long left turn pockets and/or the left turn pockets having long transitions in excess of 120’ on wide arterials, especially for 2-lane, and more, left turn pockets.

While the vehicles may actually lower their speeds when making their left turns through the intersection, the lowered speeds are lower than the speed at which the vehicles are approaching the intersection when they are within the dilemma zone. Since the primary reason for the yellow clearance is the elimination of the “dilemma zone”, using the lower turning speed of vehicles while making the turn may not be an appropriate approach to calculate the minimum yellow change interval for left turning vehicles.

Many agencies in California use a 25 MPH “Approach Speed” for the left run phases resulting in a minimum 3-second yellow change interval for left turn phases. Although this value may be appropriate in most cases, it may not adequate for all cases. Furthermore, this downward adjustment was neither recommended nor supported in any shape or form by the 2003 MUTCD and *California Supplement*.

Limited data and field observations by some jurisdictions such as City of Garden Grove, California have resulted in that jurisdiction’s increase of the minimum yellow timings to 3.2 seconds, which corresponds to a 30 MPH “Approach Speed” in Table 4D-102. However, under that approach, still all left turn phases are treated equally regardless of the intersection geometry, number of left turn pockets, length of transition, and other field conditions. Increasing the minimum yellow timing for all left turn pockets from 3 seconds to 3.2 seconds definitely

improves traffic safety, but it still may not address many field conditions, as discussed previously in this section, where the “Approach Speed” of left turning vehicles may be closer to 35 MPH requiring a minimum of 3.6 seconds yellow clearance timing.

Furthermore, due to the complete silence of the 2003 MUTCD and the *California Supplement* on allowing a lower “Approach Speed” for the protected left turn phases, any such reduction, may face a serious legal challenge at locations with automated red-light photo enforcement.

The CTCDC acknowledged the need for a more thorough review of this issue, including a comprehensive statewide data collection effort, and an engineering study to develop recommendations for these adjustments. However, to address the question at hand, until the completion of such study, the CTCDC endorsed the use of 3 seconds as the minimum value for the yellow change intervals for protected turning phases.

C. CONCLUSIONS

The CTCDC, following extensive and deliberate discussions, concluded that since the objective is to establish “minimum” values for yellow change intervals, which can be increased depending on specific field conditions and based on professional traffic engineering judgment, it may be prudent to define “Approach Speed” as the “posted speed limit”, or prima facie speed in absence of the posted speed, as this alternative is more practical and better legally defensible.

Furthermore, although the primary reason for this debate was to resolve the legal issues associated with intersections with red-light cameras, the CTCDC decided that this policy should apply to all signalized intersection in California, regardless of presence of automated red-light enforcement devices. However, the CTCDC agreed to review this issue again in one year to evaluate the impact of this decision throughout California.

As a result of the CTCDC decision, the following section was added to the *California Supplement*:

Section 4D.10 Yellow Change and Red Clearance Intervals

Support:

The purpose of the yellow signal indication is to warn traffic approaching a traffic signal that the related green movement is ending or that a red indication will be exhibited immediately thereafter and traffic will be required to stop when the red signal is exhibited. The following methodology in this section provides guidance for establishing the “minimum yellow light change interval” for traffic signals. This methodology is essentially the same as was included in Section 9-04.5 of the Caltrans 1996 Traffic Manual. The 1996 Manual used the term “approach speed” for the minimum yellow interval, which caused some confusion for the courts. The methodology in this section uses the posted speed limit or prima facie speed limit instead of approach speed. At the December 8, 2004 meeting of the California Traffic Control Devices Committee (CTCDC) there was discussion regarding the desirability of changing the methodology because some public agencies are using automated enforcement systems. The CTCDC recommended that the methodology in this section be reevaluated after a period of one year. During this one-year period, the Committee will examine whether changes need to be made in the methodology.

Standard:

The minimum yellow light change interval shall be in accordance with Table 4D-102. The posted speed limit, or the prima facie speed limit established by the California Vehicle Code (CVC) shall be used for determination of the minimum yellow light change interval for the through traffic movement. The minimum yellow light change interval for a protected left-turn or protected right-turn phase shall be 3.0 seconds.

Option:

The minimum yellow light change interval for the through movement and the protected left-turn or protected right-turn may be increased based on a field review or by using appropriate judgment. That judgment may be based on numerous factors, including, but not limited to, 85th percentile speed, and intersection geometry and field observation of traffic behavior.

Table 4D-102 Minimum Yellow Light Change Intervals

POSTED SPEED OR PRIMA FACIE SPEED		MINIMUM YELLOW INTERVAL
mph	km/hr	Seconds
25 or less	40 or less	3.0
30	48	3.2
35	56	3.6
40	64	3.9
45	72	4.3
50	80	4.7
55	89	5.0
60	97	5.4
65	105	5.8

The Table is based on the following Formula:

$$T = t + V/2d$$

Where:

T = The Minimum yellow light change interval (sec.)

V = Approach Speed (ft/sec.)

d = Deceleration rate (10 ft/sec.)

t = Reaction time (1 sec.)